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By- LeVasseur, Paul M.

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The model considered in this paper, the G.A.M.E. Educational Planning Model, provides a means of studying the interrelationships among education, manpower, and the economy. The model was originally constructed for use at the Training Seminar, Global Accounts for Manpower and Education (G.A.M.E.), held in Dublin, Ireland, September 4-20, 1967. Designed to quantify certain structural relationships within and among these systems, the model can be used in a manner which closely approximates the way in which planning is carried out in practice. The model is designed to analyze various planning decisions in terms of their consistency, and, in cases in which dysfunctions are discovered, it can be used in an iterative manner to arrive at mutually consistent and balanced plans. The model considers three separate systems: the Educational System, the Manpower System, and the Inter-industry System. The body of the paper is concerned with a qualitative description of the model, while the mathematical description of the model is contained in an appendix. (hw)

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A STUDY OF INTER-RELATIONSHIPS BETWEEN EDUCATION, MANPOWER AND ECONOMY

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I. BACKGROUND.

1. In a paper entitled Quantitative Analysis in Educational Planning: Some European Experiences presented to this Symposium by Mr. Gareth L. Williams of the O.E.C.D., current work in the construction of national planning models in several O.E.C.D. Member countries is described. As part of its programme for Systems Analysis in Educational Planning, the O.E.C.D. has obtained considerable information pertaining to these model-building efforts. As one of the O.E.C.D.'s training activities, it was decided to synthesize a number of available model-building techniques for presentation at a Training Seminar on Quantitative Techniques in Educational Planning. This Seminar, entitled Global Accounts for Manpower and Education (G.A.M.E.), was held in Dublin, Ireland during the period 4th-20th September, 1967. It was attended by 26 participants from 11 O.E.C.D. Member countries. The Seminar sought to actively engage participants in three major areas of model-building. The first area was the collection and analysis of data. The second area concerned actual model construction. The last area consisted of the use of the model by participants in a simulated planning exercise. The G.A.M.E. Educational Planning Model which was constructed by the O.E.C.D. for use in this Training Seminar is the topic of this paper.

II OBJECTIVES IN THE CHOICE OF THE MODEL

2. The G.A.M.E. Model was chosen with a number of specific objectives in mind. The first objective was that it be of a global nature. The term global, as used here, has a dual meaning. The first meaning pertains to the level of aggregation of the systems under consideration. By global we mean that the systems will be viewed at the national level. In this sense, the model is a national planning model, and for this reason excludes a number of regional aspects which might also be of interest to some countries. Because our participants came from countries in which a wide variety of different problems arise on the local level, it was decided to construct a model which was representative of problems faced by all countries at a national level.

3. The second meaning of the word global pertains to the nature of the systems which are incorporated into the model. Rather than being confined to the consideration of the educational system alone, the model extends beyond the educational system to include the manpower and economic systems. The resulting model, therefore, is one which can be used for the planning of education, manpower and the economy at the national level.

4. A second objective was that participants be introduced to structural models. By structural, we mean that the model must quantify certain structural relationships among various factors which describe the state of the three systems.

5. Another objective which was thought to be of primary importance was that the model chosen could be used in a manner which closely approximates the way in which planning is actually carried out in practice. For this reason, the model consists of three inter-locking sub-models. Because planning for education, manpower and the economy is usually carried out by different planning groups, the model permits decisions made independently in these three planning spheres to be simultaneously analysed and compared. Participants were, in fact, broken into three groups, each of which was responsible for the planning of education, manpower, or the economy. Initially, each group worked in isolation with its own sub-model. The complete G.A.M.E. Model is designed to uniformly analyse the decisions taken by each of the groups, and to trace the effects of planning decisions made for one system upon the other systems.

6. One of the important features thought essential for the model was that it address itself to problems of consistency in planning. Since there is no guarantee that plans for the education manpower and economic systems will necessarily be consistent, the model is constructed in a manner which makes it possible to test the consistency of plans for these three systems. In this way, certain dysfunctionalities which occur as a result of isolated planning decisions can be identified.

7. In cases in which inconsistencies are discovered, it is necessary that the model be iterative, in the sense that one can re-run the model after certain alternative planning decisions are considered. The G.A.M.E. Model, therefore, is an iterative model Although there are no major conceptual difficulties in incorporating iterative procedures into the computer programme which solves the model, this was not done for the Training Seminar. Rather, a man-machine interaction took place which allowed participants to see each step in the iterative process for arriving at a consistent and balanced solution.

8. In summary, it was decided that the model to be constructed would be a national planning model which simultaneously considers the education, manpower and economic systems. Designed to quantify certain structural relationships within and among these systems, the model can be used in a manner which closely approximates the way in which planning is carried out in practice. The

model is designed to analyse various planning decisions in terms of their consistency, and in cases in which dysfunctionalities are discovered, it can be used in an iterative manner to arrive at mutually consistent and balanced plans.

III. THE G.A.M.E. EDUCATIONAL PLANNING MODEL - A QUALITATIVE DESCRIPTION.

9. The model considered in this paper provides a means of studying the inter-relationships between education, manpower and the economy. In order to describe the model, it is necessary to portray the nature of the systems under consideration and the inter-actions which occur between them. A number of possible means for describing the model exist, and participants in the G.A.M.E. Seminar were able to view the model in several ways. Initially, they were introduced to a qualitative description of the model. Later, they were exposed to the actual computer programmes used to solve the model. Finally, the complete mathematical description of the model was developed and explained. For purposes of this Symposium, the body of this paper is concerned with the qualitative description of the model, the mathematical description being included in an appendix.

10. A qualitative viewpoint has been chosen for presentation in this paper because it is an extremely helpful way of looking at various phenomena which underly the relationships among the systems being modelled. In order to present a qualitative picture of the G.A.M.E. Model, it is necessary to adopt a language. The language which has been chosen draws heavily upon the work of Professor Jay W. Forrester of the Massachusetts Institute of Technology, and is described in detail in the volume entitled Industrial Dynamics. (1) The complete Industrial Dynamics approach embodies the process of constructing a flow diagram depicting relationships pertaining to the systems under consideration, writing out systems of equations describing these relationships, estimating certain parameters and using a computer to solve the equations. For the G.A.M.E. Model, only the flow diagram representing the system relationships will be shown. The flow diagram has been intentionally simplified, and for this reason only some of Professor Forrester's symbols are used, and in some cases slightly modified. The flow diagram of the model is shown in Figure 1 on the following page, and is described below.

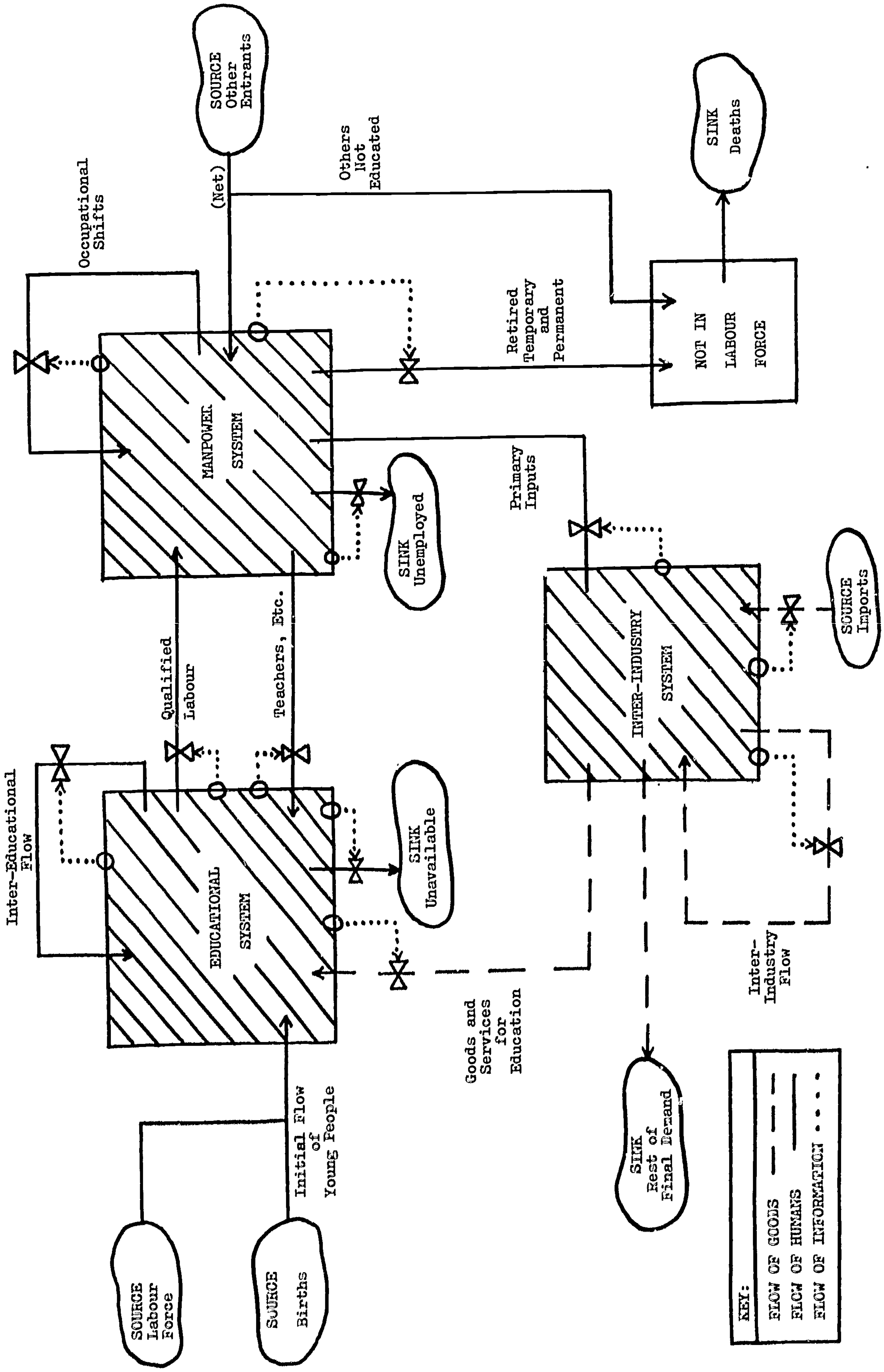
A. The Systems Under Consideration.

11. The model considers three separate systems; namely, the Educational System, the Manpower System, and the Inter-Industry System. Each of these systems is itself broken down into the elements which make up the system. These elements are as follows:

(1) Forrester, Jay W., Industrial Dynamics, The M.I.T. Press, Massachusetts Institute of Technology, Cambridge, Massachusetts, 1961.

FIGURE 1

EDUCATION, MANPOWER, INTER-INDUSTRY MODEL



1) The Educational System is broken down into distinct branches of education, which are further divided into grades of study within the branch. In some cases, it is also desirable to distinguish between fields of study within a branch;

2) The Manpower System is broken down into occupations and educational qualifications required for these occupations;

3) The Inter-Industry System is broken down into a number of distinctly defined industries which produce the goods and services required in the economy.

B. The "Levels" within the Systems.

12. At any point in time, each system, is operating at certain "Levels". These levels are defined as follows:

1) The level of the Educational System is defined to be the number of students enrolled in each branch and grade of education;

2) The level of the Manpower System is defined to be the number of individuals employed in each occupation;

3) The level of the Inter-Industry System is defined to be the level of production of each industry.

C. Flows Within and Among Systems.

13. There are two kinds of flows which take place within and among the three systems defined. These are:

1) Flows of Goods and Services;

2) Flows of Humans

14. Flows within each system can occur. The Inter-Education flow of humans represents the progress of students from one branch and grade of education to another. The Occupational Shifts flow of humans represents the changes of individuals from one occupation to another. The Inter-Industry flow of goods and services represents the flows between industries of goods and services used for intermediate and capital purposes.

15. Flows between two systems also occur. Humans flow from the Educational System to the Manpower System to provide additions to the labour force. Humans also flow from the Manpower System to the Educational System to provide the teachers and other manpower requirements for education. Humans flow from the Manpower System to the Inter-Industry System to provide labour required for production purposes. Goods and Services flow from the Inter-Industry System to the Educational System to provide the current and capital requirements for education.

16. In addition, there is a flow of humans from the Manpower System to the Inactive Population, due to retirement, inavailability, etc. The box labeled "Not in Labour Force" in Figure 1 therefore has its own level at any point in time.

D. Sources and Sinks.

17. In addition to flows within and among the systems, there are flows into systems from sources and flows out of systems into sinks. Such flows are considered to be determined in a manner which is exogenous to the model. These flows, of course, have a direct effect upon the system levels. The sources and sinks appearing in Figure 1 are described below.

18. The sources providing flows of humans into the Educational System include new entrants into education due to children reaching school age (i.e. births), persons re-entering school from the labour force, children of immigrants, etc. There is also a flow from the Educational System into a sink which would represent emigrations to other countries upon completing studies, individuals not entering the active labour force, etc. These people would be unavailable for employment within the country.

19. The source providing a flow of humans into the Manpower System would consist primarily of net immigration of persons who may or may not enter into the active labour force. The flow of humans from the Manpower System to its associated sink represents unemployed individuals seeking employment, frictional unemployment, etc. An additional sink is included to represent deaths in the population.

20. A source providing goods and services to the Inter-Industry System would consist primarily of imports. All goods and services delivered to the rest of final demand (i.e. final demand excluding education and capital investment by industry) are considered as flowing into a sink.

E. Relating Flows and Levels.

21. For each of the flows within and among the systems, there is a direct relationship between these flows and the levels of the systems themselves. As enrolments increase, for example, a greater number of individuals and a greater amount of goods and services is required to maintain the system. Similarly, as production levels change, the manpower requirements, as well as requirements for capital and intermediate goods change. At any point in time, therefore, there is a direct relationship between the levels of each system and the flows within and among the systems. Figure 1, therefore, describes these inter-relationships. Empirical measurements are required in order to determine the actual values associated with the levels and the flows.

22 Another aspect not yet discussed pertains to the rate of flow of humans as well as goods and services. This rate of flow can itself change over time. It often results from specific decisions or from technological factors. Consider the case wherein a decision was made to increase the teacher/student ratio throughout the Educational System. In this case, even though the level of enrolments is the same, the number of teachers required from the Manpower System is greater and the flow of humans from the Manpower System to the Educational System changes. This is an example of a change in the rate of flow from the Manpower System to the Educational System, and we could therefore imagine a "valve" which regulates this flow being turned so as to increase the flow. Such "valves" are represented in Figure 1 by the symbol "⋈" (decision functions) and regulated as a result of flows of information. These flows of information emanate from the systems themselves. This is to say that information pertaining to the systems themselves must be taken into account in order to determine the rates of flow which apply to each flow of humans as well as each type of goods and services. Such information can be obtained by measuring the performance of the system, or by considering specific decisions which are made within the system. The example was given above of a decision to modify the teacher/student ratio in the educational system which would effect the rate of flow of humans from the Manpower System to the Educational System. Similarly, measurements which show that university drop-outs are decreasing in the educational system would indicate that the rate of flow of university graduates to the Manpower System is increasing.

F. Dynamic Aspects of the Model.

23. The qualitative flow diagram of the G.A.M.E. Model describes inter-relationships among the systems in terms of flows of humans, goods and information. These flows, of course, take place continuously over time. The dynamic aspects of the model have not been incorporated into the flow diagram. It is helpful, however, to think of all the flows represented as being net flows within the limits of a certain time period. The G.A.M.E. Model considers flows which take place during each year of a plan period.

IV. THE MATHEMATICAL MODEL

24. Every directed line representing flows of goods and services or of humans appearing in the flow diagram can be interpreted as a set of equations applying to some year in the plan period. The equations consist of dependent and independent variables as well as a set of parameters which appear as coefficients of the variables. The "valves" in the flow diagram can be interpreted as the coefficients. It is thus possible to use the qualitative description as an aid in formulating the mathematical description of the model. The complete description of the variables, parameters and equations of the G.A.M.E. Model is given in Appendix 1. The remarks made here are confined to more general considerations of the mathematical formulation.

25. It has already been mentioned that the three systems shown in the flow diagram are themselves sub-divided so as to differentiate between educational branches and grades, qualifications, occupations and industries. It is for this reason that the flows in the diagram become sets of equations, rather than single equations. In the G.A.M.E. Model, 25 educational branches and grades, 8 educational qualifications, 20 occupations and 23 industries were distinguished. At this level of disaggregation, the model consists of 352 equations and 387 variables which must be solved for during each year of the plan period. The plan period chosen for the Seminar was 9 years. The complete G.A.M.E. Model, therefore, consists of 3,168 equations with 3,483 variables to be solved for. Each of the three groups, however, was able to use its own sub-model of the three systems. The sub-models consisted of sub-sets of the entire set of equations and in this way the work of the participants was made more manageable through a division of labour.

26. An additional simplification was introduced by solving the entire model only for the target year. Although the Education Group used a sub-model which was dynamic over the entire plan period, the other groups focused upon the target year solution of their sub-models. This procedure meant that certain simplifications were made which are not required when using the full model, but had the advantage of providing participants with an understanding of the principles underlying the model without introducing large amounts of computer data and results pertaining to each intermediate year in the plan period. The actual computer programmes used in the G.A.M.E. Seminar, therefore, were a somewhat simplified version of the complete model described in Appendix 1, in which the target year values of all variables were solved for and intermediate year variables were solved for the education system only.

V. ESTIMATING THE PARAMETERS OF THE MODEL.

27. In order to estimate the parameters for the G.A.M.E. Model, it was necessary to collect a wide range of data pertaining to education, manpower and the economy. Since the O.E.C.D is located in Paris, it was decided that data from France would be the most easily obtainable. For this reason, the definition of educational branches and grades is based upon the French educational system. The model used in the G.A M.E. Seminar, however, should not be considered to be a valid model of France. The reason for using actual country data was to assure a certain degree of realism in the basic data provided to participants and the parameters deduced from these data. It would, of course, have been possible to use completely fabricated data. An actual model for country use, nevertheless, would require that far greater attention be paid to resolving definitional and aggregation problems than was possible with the limited time and staff available for constructing the G.A.M.E. Model. The G.A.M.E.

data, therefore, must be considered to be essentially illustrative. The experience gained in the collection of data for estimating the parameters in the model did prove most encouraging in demonstrating the feasibility of constructing an empirical model of this kind for actual country use.

28. In order to estimate the parameters of the model, a base year (1962) was decided upon for which various kinds of data pertaining to education, manpower and the economy were collected. These data were brought together in an integrated accounting framework which is described in Appendix 2. The integrated set of accounts measures the flows within and between the systems during a one-year period. The flow accounts are then used to derive an integrated set of coefficients for education, manpower and the economy. These coefficients provide quantitative structural information about the systems. The coefficients are incorporated into the model as parameters, in addition to a number of additional parameters which are estimated independently from the accounts.

29. Although the mathematical model in Appendix 1 does not present the coefficients in the form of time functions, it is of course possible to use parameters which have been estimated for each year in the plan period. Some of the parameters used by the participants in the G.A.M.E. Seminar, for example, were estimated for the target year on the basis of time series information or even on the basis of certain planning goals. In other cases, however, the base year data were felt to provide parameter estimates which were applicable over the entire plan period.

VI. THE ITERATIVE PROCEDURE FOR SOLVING THE MODEL.

30. In Appendix 1, the G.A.M.E. Model is expressed as a set of relationships (equations) between exogenous and endogenous variables. In order that plans for education, manpower and the economy be consistent, these relationships must all hold in any year of the plan. Since exogenous variables represent policy variables which are set by the planners themselves, there is no guarantee that a consistent solution will be arrived at if plans which seek to fix these variables at future points in time (targets of the plan) are drawn up in isolation. In fact, the opposite will normally be the case. The purpose of the G.A.M.E. Model is precisely to analyse educational, manpower and economic plans in order to arrive at a consistent and mutually balanced solution.

31. The starting point in using the model is to postulate targets for the three systems and compute the implications of the targets for any one system upon the other systems. This procedure inevitably leads to measurable disparities. For example, an economic plan may require a given number of newly trained engineers which the educational system cannot supply. On the basis of the nature and magnitude of the disparities found to be inherent in the targets originally postulated, these targets are revised and the model re-run in an iterative manner

until a final consistent and balanced solution is achieved. In theory, it is possible to include mathematical relationships which revise the values of exogenous variables on the basis of the differences between the values of endogenous variables arrived at in each step of the iterative procedure. In this way, a completely automated iterative model could be constructed.

32. The G.A.M.E. Model does not include a computerized iterative procedure in its mathematical description. Instead, the iterations are carried out through man-machine interaction. There are a number of reasons for using this approach. From a strictly pedagogical point of view, the man-machine iterative procedure served as an excellent vehicle for demonstrating certain planning principles to the G.A.M.E. Seminar participants. There are other reasons, however, for using a man-machine approach. Among the most important of these is that this approach is closely analogous to the procedure which planners actually use for arriving at a final plan. In practice, plans set forth for different sectors are compared and subsequently revised in stages when inconsistencies are detected. The advantage of using a model is that it can test targets for education, manpower and the economy for internal and external consistency within a very comprehensive framework which permits a far greater amount of structural detail to be considered than is possible without the aid of a computer.

33. Another important reason for using the man-machine approach is that it permits targets to be revised on the basis of an analysis of the previous iteration. In many cases there may be a number of alternative revisions possible which will lead to a consistent and balanced solution. This approach permits the planners to select among those alternatives in a manner which they consider most consistent with their own goals and preferences. A completely automated approach would yield one final solution on the basis of decision rules which must necessarily be built into the model in advance of any concrete knowledge about the kinds of inconsistencies which may ultimately be found. It seems unlikely that a solution arrived at in a purely automatic fashion, not permitting the planners to fully analyse and discuss the incompatabilities, would be acceptable to the planners themselves. In addition, for purely technical reasons, automated iterative procedures often prove to be a very slow means of converging to a solution. In short, the man-machine iterative procedure is both an efficient and realistic mode of planning.

34. In the G.A.M.E. Seminar, participants in each of the three groups used the model in a simulated planning environment. The plan which was finally arrived at resulted from an interaction of the three groups during a sequence of joint meetings at which the model results were analysed, and targets were revised. A more detailed description of the G.A.M.E. Simulation Exercise is given in Appendix 3.

VII. THE POTENTIAL OF THE G.A.M.E. MODEL FOR PLANNING AND POLICY-MAKING.

35. It was stated at the outset that the model described in this paper was constructed for use at the O.E.C.D. Training Seminar on Quantitative Techniques in Educational Planning. The O.E.C.D. plans to publish the content of this Seminar in detail in a separate document. Although the G.A.M.E. Model was initially constructed for didactic purposes, it may be well to consider the potential of such a model for planning and policy-making.

36. The strength of the model lies in the fact that it incorporates relationships between education, manpower and the economy within a single, comprehensive framework. All too often educational plans are drawn up without consideration of their implications for manpower and the economy. Similarly, economic plans are made without sufficient attention being paid to the investments which must be made in education if the manpower required to meet the targets of the plan is to be available when needed. The model described in this paper makes explicit certain structural relationships between education, manpower and the economy which must be considered if consistent planning at the national level is to be achieved. Although it is confined to a global, national viewpoint, the span of variables considered includes levels of enrolments in different branches of education, manpower requirements for education, requirements of goods and services for education, the educational qualifications of the labour force, manpower requirements for the economy and the levels of production in the economy. All of these factors are of extreme importance for planning at the national level.

37. The model is policy-oriented, and for this reason would be of considerable importance for policy formulation and evaluation. An example of the kind of national educational policy-making to which this model addresses itself can be taken directly from the United States. The National Defense Education Act was specifically designed with a view toward increasing the levels of enrolment in certain areas of education. This policy was a direct result of certain manpower and economic requirements which needed to be met. The model described in this paper provides a mechanism for continually analysing and up-dating national policy on the basis of economic and social goals. The model can be used to trace the effects of proposed alternative national educational policies upon the manpower and economic systems, and thus provide guidelines for the evolution of the educational system.

38. In designing the model, a conscious effort has been made to arrive at a "generalised" formulation. Since educational systems differ from country to country, the model defines educational branches, grades and qualifications in a manner which is sufficiently flexible to permit it to be applied to any country. The generalised approach enhances its potential for use by a large number of countries which might be interested in using a planning aid of this kind. The model, in this sense, is not confined to any particular educational environment.

39. Finally, the experience gained by the O.E.C.D. in constructing the G.A.M.E. Model for didactic purposes should be reviewed in any discussion of the model's potential for planning and policy-making. It has already been mentioned that the decision to collect actual country data has demonstrated the feasibility of constructing such a model. In fact, the process of constructing such a model provides considerable information for establishing data collecting priorities. Creating a simulated environment in which the model was actually used offered an excellent opportunity to judge the model's viability as an instrument for rational policy formulation. The conclusion arrived at is that a model of this kind offers considerable potential for the formulation of consistent national plans and policy in the areas of education, manpower and the economy.

40. The O.E.C.D. plans to continue to study the interrelationships between education, manpower and the economy. It is planned that the work being carried out in Member countries in the area of mathematical models for educational planning will be further encouraged and synthesized by the O.E.C.D. through the establishment of a co-operative programme in this area. Ultimately, it is possible that the O.E.C.D. may be able to make available to its Member countries a mathematical model which they can use to assist them in educational policy evaluation. Such a model would undoubtedly incorporate many considerations which are not found in the model described in this paper. The G.A.M.E. Educational Planning Model might nonetheless be considered to provide a first step in this direction.

APPENDIX I

MATHEMATICAL DESCRIPTION OF THE G.A.M.E. EDUCATIONAL PLANNING MODEL

MATHEMATICAL DESCRIPTION OF THE G.A.M.E. EDUCATIONAL PLANNING MODEL

SYMBOL DEFINITIONS

1. DIMENSIONS

N - Number of industries

M - Number of occupations

Q - Number of educational qualifications

H - Number of branches of education

G - Total Number of branches and grades of education

T - Number of years in the plan period

2. INDICES

i,j	-	Indices referring to an industry ($i,j = 1,2, \ldots ,N$)
k,k'	-	Indices referring to an occupation ($k,k' = 1,2, \ldots ,M$)
q	-	Index referring to an educational qualification ($q = 1,2, \ldots ,Q$)
h	-	Index referring to a branch of education ($h = 1,2, \ldots ,H$)
g,g'	-	Indices referring to a branch and grade of education ($g,g' = 1,2, \ldots ,G$)
N_h	-	Number of grades in branch h of education ($\sum_{h=1}^{H} N_h = G$)
t	-	Year in the plan period ($t = 1,2, \ldots ,T$)
0	-	Base year

3. COEFFICIENTS

$z_{i,j}$	-	Coefficient of direct and indirect requirements for goods produced by industry i per unit of output in industry j.
$k^{(1)}_{i,j}$	-	Capital coefficient for industry representing the amount of capital good required from industry i per unit of output in industry j.
$\nu^{(1)}_{k,j}$	-	Manpower coefficient for industry representing the number of individuals in occupation k required per unit of output in industry j.
γ_k	-	Annual labour force attrition rate for occupation k.
$\psi_{k,k'}$	-	Labour force mobility coefficient representing the proportion of individuals who move from occupation k to occupation k' in a one-year period.

$\omega_{q,k}$ - Occupation-educational qualification coefficient representing the proportion of individuals with qualification q in occupation k.

$\nu^{(2)}_{k,h}$ - Manpower coefficient for education representing the number of individuals in occupation k required per student enrolled in branch h.

$\tau^{(E)}_{g,g'}(t)$ - Inter-educational transition coefficient representing the proportion of students enrolled in branch and grade g in year t-1 who are enrolled in branch and grade g' in year t.

$\tau^{(L)}_{g,q}(t)$ - School-leaver transition coefficient representing the proportion of students enrolled in branch and grade g in year t-1 who are in the active labour force with educational qualification q in year t.

$\tau^{(D)}_{g}(t)$ - Student mortality coefficient representing the annual mortality rate of students enrolled in branch and grade g in year t.

$\tau^{(I)}_{g}(t)$ - School-leaver non-participation rate representing the proportion of students enrolled in branch and grade g in year t who have left the school system in year t+1 but will not be available for the active labour force.

$a_{i,h}$ - Input-output coefficient for education representing the requirements for non-capital goods from industry i per student enrolled in branch h.

$k^{(2)}_{i,h}$ - Capital coefficient for education representing the amount of capital good required from industry i per student enrolled in branch h.

4. VARIABLES

$X_i(t)$ - Total production of industry i in year t.

$Y_i(t)$ - Total final deliveries by industry i in year t.

$Y^{(KIN)}_i(t)$ - Deliveries by industry i of capital investment goods for industry in year t.

$Y^{(CED)}_i(t)$ - Deliveries by industry i of non-capital goods for education in year t.

$Y^{(KED)}_i(t)$ - Deliveries by industry i of capital goods for education in year t.

$Y^{(RFD)}_i(t)$ - Deliveries by industry i to all other final demand sectors (i.e. excluding industrial investment and education) in year t.

$N_k(t)$ - Total number of individuals in labour force with occupation k in year t.

$N^{(1)}_k(t)$ - Number of individuals in occupation k employed by industry in year t.

$N^{(S)}_K(t)$ - Number of survivors in occupation k' in year t from manpower stock in year t-1 (net of new entrants from the educational system).

$N^{(2)}_k(t)$ - Number of individuals in occupation k employed by education in year t.

$N_k^{(RFD)}(t)$ - Number of individuals in occupation k employed by other final demand sectors (i.e. excluding education) in year t.

$N_k^{(R)}(t)$ - Number of new entrants into the labour force from the educational system required in year t.

$L_q^{'}(t)$ - Number of school leavers with qualification q available for the labour force in year t.

$S_h^{'}(t)$ - Number of students enrolled in branch h in year t.

$S_g(t)$ - Number of students enrolled in branch and grade g in year t.

$E_{g'}(t)$ - Number of new entrants into grade g' (from outside the educational system in year t.

$\Delta \tau_{g,g'}^{(E)}(t)$ - Change in the value of the inter-educational transition coefficient $\tau_{g,g'}^{(E)}(t)$ between years t-1 and t.

$\Delta \tau_{g,q}^{(L)}(t)$ - Change in the value of the school-leaver transition coefficient $\tau_{g,q}^{(L)}(t)$ between years t-1 and t.

RELATIONSHIPS FOR THE ECONOMY

$$
(1)\quad \left\{
\begin{aligned}
X_1(t) &= z_{1,1}Y_1(t) + z_{1,2}Y_2(t) + \cdots + z_{1,j}Y_j(t) + \cdots + z_{1,N}Y_N(t) \\
X_2(t) &= z_{2,1}Y_1(t) + z_{2,2}Y_2(t) + \cdots + z_{2,j}Y_j(t) + \cdots + z_{2,N}Y_N(t) \\
&- \quad - \quad - \quad - \quad - \quad - \\
X_i(t) &= z_{i,1}Y_1(t) + z_{i,2}Y_2(t) + \cdots + z_{i,j}Y_j(t) + \cdots + z_{i,N}Y_N(t) \\
&- \quad - \quad - \quad - \quad - \quad - \\
X_N(t) &= z_{N,1}Y_1(t) + z_{N,2}Y_2(t) + \cdots + z_{N,j}Y_j(t) + \cdots + z_{N,N}Y_N(t)
\end{aligned}
\right.
$$

Equations (1) are the Leontief input-output relationships.

$$
(2)\quad \left\{
\begin{aligned}
Y_1^{(KIN)}(t) &= k_{1,1}^{(1)}[X_1(t+1)-X_1(t)] + \cdots + k_{1,j}^{(1)}[X_j(t+1)-X_j(t)] + \cdots + k_{1,N}^{(1)}[X_N(t+1)-X_N(t)] \\
Y_2^{(KIN)}(t) &= k_{2,1}^{(1)}[X_1(t+1)-X_1(t)] + \cdots + k_{2,j}^{(1)}[X_j(t+1)-X_j(t)] + \cdots + k_{2,N}^{(1)}[X_N(t+1)-X_N(t)] \\
&- \quad - \quad - \quad - \quad - \quad - \\
Y_i^{(KIN)}(t) &= k_{i,1}^{(1)}[X_1(t+1)-X_1(t)] + \cdots + k_{i,j}^{(1)}[X_j(t+1)-X_j(t)] + \cdots + k_{i,N}^{(1)}[X_N(t+1)-X_N(t)] \\
&- \quad - \quad - \quad - \quad - \quad - \\
Y_N^{(KIN)}(t) &= k_{N,1}^{(1)}[X_1(t+1)-X_1(t)] + \cdots + k_{N,j}^{(1)}[X_j(t+1)-X_j(t)] + \cdots + k_{N,N}^{(1)}[X_N(t+1)-X_N(t)]
\end{aligned}
\right.
$$

Equations (2) assume a gestation period of one year for all capital deliveries. It is also possible to provide for variable gestation periods by type of good.

RELATIONSHIPS FOR THE ECONOMY (Continued)

$$
(3)\quad \left\{
\begin{array}{lcl}
Y_1(t) & = & Y_1^{(KIN)}(t)^* + Y_1^{(CED)}(t)^* + Y_1^{(KED)}(t)^* + Y_1^{(RFD)}(t)^* \\
Y_2(t) & = & Y_2^{(KIN)}(t)^* + Y_2^{(CED)}(t)^* + Y_2^{(KED)}(t)^* + Y_2^{(RFD)}(t)^* \\
- & & - \quad\quad - \quad\quad - \quad\quad - \\
Y_i(t) & = & Y_i^{(KIN)}(t)^* + Y_i^{(CED)}(t)^* + Y_i^{(KED)}(t)^* + Y_i^{(RFD)}(t)^* \\
- & & - \quad\quad - \quad\quad - \quad\quad - \\
Y_N(t) & = & Y_N^{(KIN)}(t)^* + Y_N^{(CED)}(t)^* + Y_N^{(KED)}(t)^* + Y_N^{(RFD)}(t)^*
\end{array}
\right.
$$

In equations (3), the values marked "*" were target values for the economic programme in the G.A.M.E. Seminar. These values were set by the Economic Group at the start of the Simulation Exercise on the basis of their preferences for the economy.

RELATIONSHIPS FOR THE ECONOMY AND MANPOWER

$$
(4)\quad \left\{
\begin{array}{lcl}
N_1^{(1)}(t) & = & \nu_{1,1}^{(1)} X_1(t) + \nu_{1,2}^{(1)} X_2(t) + \cdots + \nu_{1,j}^{(1)} X_j(t) + \cdots + \nu_{1,N}^{(1)} X_N(t) \\
N_2^{(1)}(t) & = & \nu_{2,1}^{(1)} X_1(t) + \nu_{2,2}^{(1)} X_2(t) + \cdots + \nu_{2,j}^{(1)} X_j(t) + \cdots + \nu_{2,N}^{(1)} X_N(t) \\
- & & - \quad\quad - \quad\quad - \quad\quad - \quad\quad - \quad\quad - \\
N_k^{(1)}(t) & = & \nu_{k,1}^{(1)} X_1(t) + \nu_{k,2}^{(1)} X_2(t) + \cdots + \nu_{k,j}^{(1)} X_j(t) + \cdots + \nu_{k,N}^{(1)} X_N(t) \\
- & & - \quad\quad - \quad\quad - \quad\quad - \quad\quad - \quad\quad - \\
N_M^{(1)}(t) & = & \nu_{M,1}^{(1)} X_1(t) + \nu_{M,2}^{(1)} X_2(t) + \cdots + \nu_{M,j}^{(1)} X_j(t) + \cdots + \nu_{M,N}^{(1)} X_N(t)
\end{array}
\right.
$$

RELATIONSHIPS FOR MANPOWER

$$
(5)\left\{
\begin{array}{lcl}
N_1^{(S)}(t) & = & \psi_{1,1}(\gamma_1 \cdot N_1(t-1)) + \cdots + \psi_{K,1}(\gamma_K \cdot N_K(t-1)) + \cdots + \psi_{M,1}(\gamma_M \cdot N_M(t-1)) \\
N_2^{(S)}(t) & = & \psi_{1,2}(\gamma_1 \cdot N_1(t-1)) + \cdots + \psi_{K,2}(\gamma_K \cdot N_K(t-1)) + \cdots + \psi_{M,2}(\gamma_M \cdot N_M(t-1)) \\
- & & - \quad - \quad - \quad - \quad - \\
N_{K'}^{(S)}(t) & = & \psi_{1,K'}(\gamma_1 \cdot N_1(t-1)) + \cdots + \psi_{K,K'}(\gamma_K \cdot N_K(t-1)) + \cdots + \psi_{M,K'}(\gamma_M \cdot N_M(t-1)) \\
- & & - \quad - \quad - \quad - \quad - \\
N_M^{(S)}(t) & = & \psi_{1,M}(\gamma_1 \cdot N_1(t-1)) + \cdots + \psi_{K,M}(\gamma_K \cdot N_K(t-1)) + \cdots + \psi_{M,M}(\gamma_M \cdot N_M(t-1))
\end{array}
\right.
$$

$$
(6)\left\{
\begin{array}{lcl}
N_1^{(R)}(t) & = & N_1^{(1)}(t)^* + N_1^{(2)}(t)^* + N_1^{(RFD)}(t)^* - N_1^{(S)}(t) \\
N_2^{(R)}(t) & = & N_2^{(1)}(t)^* + N_2^{(2)}(t)^* + N_2^{(RFD)}(t)^* - N_2^{(S)}(t) \\
- & & - \quad - \quad - \quad - \\
N_K^{(R)}(t) & = & N_K^{(1)}(t)^* + N_K^{(2)}(t)^* + N_K^{(RFD)}(t)^* - N_K^{(S)}(t) \\
- & & - \quad - \quad - \quad - \\
N_M^{(R)}(t) & = & N_M^{(1)}(t)^* + N_M^{(2)}(t)^* + N_M^{(RFD)}(t)^* - N_M^{(S)}(t)
\end{array}
\right.
$$

In equations (6), the values marked "*" were target values for the manpower programme in the G.A.M.E. Seminar. These values were set by the Manpower Group at the start of the Simulation Exercise on the basis of their preferences for the labour force.

RELATIONSHIPS FOR MANPOWER AND EDUCATION

$$
(7)\quad \left\{
\begin{aligned}
L_1(t) &= \omega_{1,1} N_1^{(R)}(t) + \omega_{1,2} N_2^{(R)}(t) + \cdots + \omega_{1,k} N_k^{(R)}(t) + \cdots + \omega_{1,M} N_M^{(R)}(t) \\
L_2(t) &= \omega_{2,1} N_1^{(R)}(t) + \omega_{2,2} N_2^{(R)}(t) + \cdots + \omega_{2,k} N_k^{(R)}(t) + \cdots + \omega_{2,M} N_M^{(R)}(t) \\
&\vdots \\
L_q(t) &= \omega_{q,1} N_1^{(R)}(t) + \omega_{q,2} N_2^{(R)}(t) + \cdots + \omega_{q,k} N_k^{(R)}(t) + \cdots + \omega_{q,M} N_M^{(R)}(t) \\
&\vdots \\
L_Q(t) &= \omega_{Q,1} N_1^{(R)}(t) + \omega_{Q,2} N_2^{(R)}(t) + \cdots + \omega_{Q,k} N_k^{(R)}(t) + \cdots + \omega_{Q,M} N_M^{(R)}(t)
\end{aligned}
\right.
$$

$$
(8)\quad \left\{
\begin{aligned}
N_1^{(2)}(t) &= \nu_{1,1}^{(2)} S_1'(t) + \nu_{1,2}^{(2)} S_2'(t) + \cdots + \nu_{1,h}^{(2)} S_h'(t) + \cdots + \nu_{1,H}^{(2)} S_H'(t) \\
N_2^{(2)}(t) &= \nu_{2,1}^{(2)} S_1'(t) + \nu_{2,2}^{(2)} S_2'(t) + \cdots + \nu_{2,h}^{(2)} S_h'(t) + \cdots + \nu_{2,H}^{(2)} S_H'(t) \\
&\vdots \\
N_k^{(2)}(t) &= \nu_{k,1}^{(2)} S_1'(t) + \nu_{k,2}^{(2)} S_2'(t) + \cdots + \nu_{k,h}^{(2)} S_h'(t) + \cdots + \nu_{k,H}^{(2)} S_H'(t) \\
&\vdots \\
N_M^{(2)}(t) &= \nu_{M,1}^{(2)} S_1'(t) + \nu_{M,2}^{(2)} S_2'(t) + \cdots + \nu_{M,h}^{(2)} S_h'(t) + \cdots + \nu_{M,H}^{(2)} S_H'(t)
\end{aligned}
\right.
$$

RELATIONSHIPS FOR EDUCATION

$$
(9)\quad \left\{
\begin{array}{l}
S_1(t) = \tau_{1,1}^{(E)}(t)\cdot S_1(t-1) + \tau_{2,1}^{(E)}(t)\cdot S_2(t-1) + \cdots + \tau_{g,1}^{(E)}(t)\cdot S_g(t-1) + \cdots + \tau_{G,1}^{(E)}(t)\cdot S_G(t-1) + E_1(t) \\
S_2(t) = \tau_{1,2}^{(E)}(t)\cdot S_1(t-1) + \tau_{2,2}^{(E)}(t)\cdot S_2(t-1) + \cdots + \tau_{g,2}^{(E)}(t)\cdot S_g(t-1) + \cdots + \tau_{G,2}^{(E)}(t)\cdot S_G(t-1) + E_2(t) \\
- \quad - \quad - \quad - \quad - \quad - \quad - \quad - \\
S_{g'}(t) = \tau_{1,g'}^{(E)}(t)\cdot S_1(t-1) + \tau_{2,g'}^{(E)}(t)\cdot S_2(t-1) + \cdots + \tau_{g,g'}^{(E)}(t)\cdot S_g(t-1) + \cdots + \tau_{G,g'}^{(E)}(t)\cdot S_G(t-1) + E_{g'}(t) \\
- \quad - \quad - \quad - \quad - \quad - \quad - \quad - \\
S_G(t) = \tau_{1,G}^{(E)}(t)\cdot S_1(t-1) + \tau_{2,G}^{(E)}(t)\cdot S_2(t-1) + \cdots + \tau_{g,G}^{(E)}(t)\cdot S_g(t-1) + \cdots + \tau_{G,G}^{(E)}(t)\cdot S_G(t-1) + E_G(t)
\end{array}
\right.
$$

$$
(10)\quad \left\{
\begin{array}{l}
L_1(t) = \tau_{1,1}^{(L)}(t)\cdot S_1(t-1) + \tau_{2,1}^{(L)}(t)\cdot S_2(t-1) + \cdots + \tau_{g,1}^{(L)}(t)\cdot S_g(t-1) + \cdots + \tau_{G,1}^{(L)}(t)\cdot S_G(t-1) \\
L_2(t) = \tau_{1,2}^{(L)}(t)\cdot S_1(t-1) + \tau_{2,2}^{(L)}(t)\cdot S_2(t-1) + \cdots + \tau_{g,2}^{(L)}(t)\cdot S_g(t-1) + \cdots + \tau_{G,2}^{(L)}(t)\cdot S_G(t-1) \\
- \quad - \quad - \quad - \quad - \quad - \quad - \\
L_g(t) = \tau_{1,g}^{(L)}(t)\cdot S_1(t-1) + \tau_{2,g}^{(L)}(t)\cdot S_2(t-1) + \cdots + \tau_{g,g}^{(L)}(t)\cdot S_g(t-1) + \cdots + \tau_{G,g}^{(L)}(t)\cdot S_G(t-1) \\
- \quad - \quad - \quad - \quad - \quad - \quad - \\
L_Q(t) = \tau_{1,Q}^{(L)}(t)\cdot S_1(t-1) + \tau_{2,Q}^{(L)}(t)\cdot S_2(t-1) + \cdots + \tau_{g,Q}^{(L)}(t)\cdot S_g(t-1) + \cdots + \tau_{G,Q}^{(L)}(t)\cdot S_G(t-1)
\end{array}
\right.
$$

RELATIONSHIPS FOR EDUCATION (Continued)

$$
(11)\left\{
\begin{array}{lll}
\tau_{g,g'}^{(E)}(t) = \tau_{g,g'}^{(E)}(t-1) + \Delta\tau_{g,g'}^{(E)}(t)^{*} & & (g = 1, 2, \ldots, G) \\
 & & (g' = 1, 2, \ldots, G) \\
\tau_{g,q}^{(L)}(t) = \tau_{g,q}^{(L)}(t-1) + \Delta\tau_{g,q}^{(L)}(t)^{*} & & (g = 1, 2, \ldots, G) \\
 & & (q = 1, 2, \ldots, Q)
\end{array}
\right.
$$

In equations (11), the values marked "*" were target values for the education programme in the G.A.M.E. Seminar. These values were set by the Education Group at the start of the Simulation Exercise on the basis of their preferences for education.

$$
(12)\left\{
\begin{array}{l}
\tau_{1,1}^{(E)}(t) + \cdots + \tau_{1,G}^{(E)}(t) + \tau_{1,1}^{(L)}(t) + \cdots + \tau_{1,Q}^{(L)}(t) + \tau_{1}^{(D)}(t) + \tau_{1}^{(I)}(t) = 1.0 \\
\tau_{2,1}^{(E)}(t) + \cdots + \tau_{2,G}^{(E)}(t) + \tau_{2,1}^{(L)}(t) + \cdots + \tau_{2,Q}^{(L)}(t) + \tau_{2}^{(D)}(t) + \tau_{2}^{(I)}(t) = 1.0 \\
- \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \\
\tau_{g,1}^{(E)}(t) + \cdots + \tau_{g,G}^{(E)}(t) + \tau_{g,1}^{(L)}(t) + \cdots + \tau_{g,Q}^{(L)}(t) + \tau_{g}^{(D)}(t) + \tau_{g}^{(I)}(t) = 1.0 \\
- \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \\
\tau_{G,1}^{(E)}(t) + \cdots + \tau_{G,G}^{(E)}(t) + \tau_{G,1}^{(L)}(t) + \cdots + \tau_{G,Q}^{(L)}(t) + \tau_{G}^{(D)}(t) + \tau_{G}^{(I)}(t) = 1.0
\end{array}
\right.
$$

RELATIONSHIPS FOR EDUCATION (Continued)

$$(13)\left\{\begin{aligned}
S_1'(t) &= S_1(t) + S_2(t) + \cdots + S_{n_1}(t)\\
S_2'(t) &= S_{n_1+1}(t) + S_{n_1+2}(t) + \cdots + S_{n_1+n_2}(t)\\
- \quad &- \quad - \quad - \quad -\\
S_H'(t) &= S_{G-n_H+1}(t) + S_{G-n_H+2}(t) + \cdots + S_G(t)
\end{aligned}\right.$$

Equations (13) sum the enrolments in each grade within a branch to obtain total enrolments by branch.

RELATIONSHIPS FOR EDUCATION AND THE ECONOMY

$$(14)\left\{\begin{aligned}
Y_1^{(CED)}(t) &= a_{1,1}S_1'(t) + a_{1,2}S_2'(t) + \cdots + a_{1,h}S_h'(t) + \cdots + a_{1,H}S_H'(t)\\
Y_2^{(CED)}(t) &= a_{2,1}S_1'(t) + a_{2,2}S_2'(t) + \cdots + a_{2,h}S_h'(t) + \cdots + a_{2,H}S_H'(t)\\
- \quad &- \quad - \quad - \quad - \quad - \quad -\\
Y_i^{(CED)}(t) &= a_{i,1}S_1'(t) + a_{i,2}S_2'(t) + \cdots + a_{i,h}S_h'(t) + \cdots + a_{i,H}S_H'(t)\\
- \quad &- \quad - \quad - \quad - \quad - \quad -\\
Y_N^{(CED)}(t) &= a_{N,1}S_1'(t) + a_{N,2}S_2'(t) + \cdots + a_{N,h}S_h'(t) + \cdots + a_{N,H}S_H'(t)
\end{aligned}\right.$$

RELATIONSHIPS FOR EDUCATION AND THE ECONOMY (Continued)

$$
(15)\left\{
\begin{array}{lcl}
Y_1^{(KED)}(t) & = & k_{1,1}^{(2)}\left[S_1'(t+1)-S_1'(t)\right] + \cdots + k_{1,h}^{(2)}\left[S_h'(t+1)-S_h'(t)\right] + k_{1,H}^{(2)}\left[S_H'(t+1)-S_H'(t)\right] \\
Y_2^{(KED)}(t) & = & k_{2,1}^{(2)}\left[S_1'(t+1)-S_1'(t)\right] + \cdots + k_{2,h}^{(2)}\left[S_h'(t+1)-S_h'(t)\right] + k_{2,H}^{(2)}\left[S_H'(t+1)-S_H'(t)\right] \\
- & - & - \quad - \quad - \quad - \quad - \quad - \\
Y_i^{(KED)}(t) & = & k_{i,1}^{(2)}\left[S_1'(t+1)-S_1'(t)\right] + \cdots + k_{i,h}^{(2)}\left[S_h'(t+1)-S_h'(t)\right] + k_{i,H}^{(2)}\left[S_H'(t+1)-S_H'(t)\right] \\
- & - & - \quad - \quad - \quad - \quad - \quad - \\
Y_N^{(KED)}(t) & = & k_{N,1}^{(2)}\left[S_1'(t+1)-S_1'(t)\right] + \cdots + k_{N,h}^{(2)}\left[S_h'(t+1)-S_h'(t)\right] + k_{N,H}^{(2)}\left[S_H'(t+1)-S_H'(t)\right]
\end{array}
\right.
$$

Equations (15) assume a gestation period of one year for all capital deliveries. It is also possible to provide for variable gestation periods by type of good.

Note: The above equations (1) through (15) apply for $t = 1, 2, \ldots, T$. The values of the variables for $t = 0$ and, in some cases, $t = T+1$, provide boundary conditions upon the solution.

APPENDIX 2

AN INTEGRATED SET OF ACCOUNTS FOR EDUCATION, MANPOWER, AND THE ECONOMY

AN INTEGRATED SET OF ACCOUNTS FOR EDUCATION, MANPOWER, AND THE ECONOMY

INTRODUCTION.

The basic classifications to be used in compiling the accounts is first described, followed by a description of the accounts themselves.

I CLASSIFICATIONS.

1. There are four basic classifications to be used in compiling the accounts. These classifications deal with Industries, Occupations, Educational Qualifications, and Branches of Education, and are discussed below.

A. Industrial Classifications.

2. Industrial Classifications are used for purposes of distinguishing among various types of industries in the economy. Such classifications are in wide use throughout the world. For standardization purposes, an International Standard Industrial Classification has been defined by the United Nations (1) and although many countries have developed their own industrial classifications, most are in general conformity with the international standard.

3. The set of accounts proposed in this article includes as one of its elements the Input-Output table for the economy. The Input-Output table describes the purchases and deliveries of intermediate goods by industrial branch, as well as the deliveries of goods from each branch to the final demand sectors. (2) In addition, it is proposed that purchases and deliveries of capital goods be treated in the same manner, incorporating a table of flows of capital goods into the accounts. A number of countries are beginning to compile such tables.

B. Occupational Classifications.

4. Occupational classifications are used for purposes of distinguishing among the different occupations held by the labour force. Such classifications are used in compiling information

---

(1) International Standard Industrial Classification of All Economic Activities, Statistical Office of the United Nations, United Nations, New York

(2) For an example of the United States Input-Output methodology, see "The Interindustry Structure of the United States, A Report on the 1958 Input-Output Study", Survey of Current Business, November, 1964, U.S. Department of Commerce.

from population censuses. For purposes of standardization, an International Standard Classification of Occupations (I.S.C.O.) has been defined by the International Labour Office (1) and although many countries have developed their own occupational classifications, most are in general conformity with the international standard.

5. The set of accounts proposed in this article includes table which relate occupation to both industry and educational qualification. These tables are to be compiled from the census of population or suitable surveys in a manner which is compatible with the industrial and educational qualification classifications chosen. The educational qualification classification is discussed below.

C. Educational Qualification Classifications.

6. A classification of educational qualifications permits an individual to be classified by the highest level of education which he has achieved. In most cases, only formal education will be considered, except where "informal" education is of such a nature that it can be easily identified by means of special diplomas or some other standardized mechanism which indicates successful completion of a certain amount of "informal" education. A classification of educational qualifications could combine both the highest diploma or degree obtained and any additional years of study at a higher level for which a diploma was not awarded. In addition, the branch of study for secondary education and field of study for higher education could also be included A standardized classification of educational qualifications has been recommended by the O.E.C.D. (1)

7. The set of accounts proposed utilizes a classification of educational qualifications both for purposes of relating the qualifications of the labour force to the occupations held by members of the labour force (as indicated in B above), as well as for purposes of classifying the school leavers during any given year.

D. Classification of Educational Branches.

8. A classification of the various branches in the educational system permits students to be classified according to their progress through the educational system. Such a classification would include all branches of education at primary, secondary and higher education levels, and each year of study within the branch. In addition, it would be desirable, as in the case of educational qualifications, to classify higher education according to field of study. A standardized classification of the educational system has been proposed by the O.E.C D. (2)

---

(1) Methods and Statistical Needs for Educational Planning, Directorate for Scientific Affaris, O E.C.D., Paris, France, 1967.

(2) Ibid.

9. The set of accounts proposed utilizes the classification of education for purposes of relating school leavers to their educational qualification upon leaving school (as stated in C above). Also, the flows of individuals within the educational system in a one year period is used in the accounts, and these flows are recorded according to the educational classification chosen. Finally, educational costs, both current and capital, during a one-year period are broken down by branch of education (defined by the educational classification) according to the industries from which goods are purchased (defined by the industrial classification).

E. Use of the Classifications.

10. Having defined the four classifications to be used, the pertinent data is assembled according to the various flow tables required to complete the accounts. The accounts record, for a given year, the flows of goods and services, as well as manpower, used by industry and education. The integrated set of accounts is described below.

II. THE INTEGRATED ACCOUNTS.

11. Figure 1 on the following page illustrates the principal components of an integrated set of accounts for education, manpower and industry. This set of accounts is assumed to apply to a one year period, and care must be taken to assure reasonable compatibility between data which may have been collected at different times during a given year. The degree of compatibility achieved, however, is primarily a matter of definition to be considered during the construction of the accounts, and will not be treated explicitly here. The dimensions of each of the tables appearing in the accounts will depend upon the classifications used. Figure 1 indicates both the names of the tables as well as the symbols used to refer to them mathematically. The meaning of each of the tables is reviewed below.

1. Inter-Industrial Flows of Goods and Services (X_1).

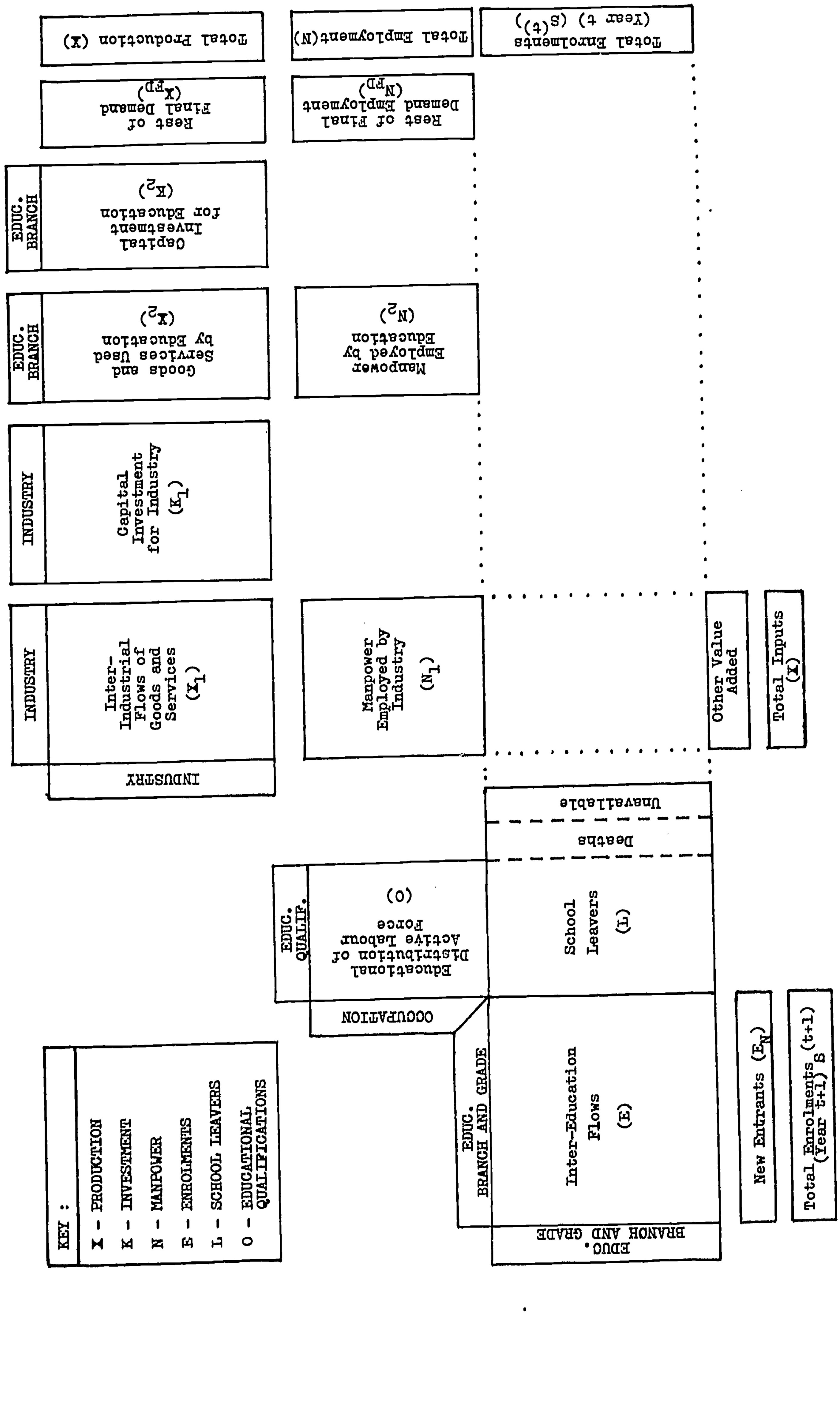
12. This table is the inter-industry transactions table for the economy for the chosen year. It is a square table, the number of rows and columns being exactly equal to the number of industries defined according to the industrial classification. The table shows the sales and purchases of goods and services by industry. Row 1, for example, shows the amount of goods delivered by Industry 1 to each of the other industries (including itself). Alternatively, Column 1 shows the amount purchased by Industry 1 from each of the other industries (including itself). An example of an entry in this table would be the amount of electricity purchased by the steel industry during one year. All of these goods and services are used for intermediate purposes in the production process. Purchases of capital goods are excluded. The dimension of the inter-industry transactions table used in the G.A.M.E. Seminar is 23-by-23.

2. Capital Investment for Industry (K_1).

13. This table is similar to (X_1). Whereas the flows of

FIGURE I

EDUCATION, MANPOWER, INTER-INDUSTRY ACCOUNTS



intermediate goods are recorded in table (X_1), the flows of capital goods are recorded in table (K_1). Thus, the entries in (K_1) form a part of final demand. For each industry producing capital goods, the row representing that industry will contain the amount of capital goods sold to each of the other industries (including itself) during the given year. Rows representing non-capital good producing industries will contain zero values. Alternatively, each column indicates the purchases of capital goods by that industry during the given year. A typical entry in the table would be the amount of capital equipment purchased from the non-electrical machinery sector by the food products sector. This entry would appear at the intersection of the row representing the non-electrical machinery sector and the column representing the food products sector. The dimension of the inter-industry capital investment transactions table used in the G.A M.E. Seminar is 23-by-23.

3. Goods and Services Used by Education (X_2).

14. This table shows the purchases during the given year for each educational branch of goods and services on current account by delivering industry. It therefore has the same number of rows as industries defined. The number of columns (educational branches) depends on the classification of education. Since it is normally impossible to divide educational expenditures according to each individual grade in a given educational branch, the branches will not be subdivided into grades of study, but will nevertheless conform to the chosen educational classification. Each row of the table represents the deliveries or non-capital goods and services by the industry represented by that row to each branch of education. Alternatively, each column represents the purchases of goods and services on current account by that branch of education from the industry producing the good or service. A typical entry in the table would be the amount purchased by the Upper Secondary Vocational branch on current account from the printing and publishing industry during the given year. This entry would appear at the intersection of the row representing the printing and publishing industry and the column representing the Upper Secondary Vocational branch. Entries in this table represent a portion of goods and services delivered to final demand. The dimension of the table of goods and services for education (current account) used in the G.A.M.E. Seminar is 23-by-7.

4. Capital Investment for Education (K_2).

15. This table shows the expenditures for capital investment of each branch of education in the given year by industry producing the capital goods delivered. Each row, therefore, indicates the capital goods delivered during the given year by the industry represented by that row to each branch of education.

Non-capital goods producing industries will have zero entries. The columns indicate the total pruchases by the branch of education of goods produced by each of the capital-goods producing industries. A typical entry in this table would be the amount of capital investment goods purchased by the Upper Secondary General branch from the construction sector during the given year. This entry would appear at the intersection of the row representing the construction sector and the column representing the Upper Secondary General branch. Entries in this table represent a portion of goods delivered to final demand. The table of investment goods purchased by education used in the G.A.M.E. Seminar is of dimension 23-by-7.

5. Flows of Goods and Services to the Rest of Final Demand (X_{FD}).

16. This table represents the deliveries of goods and services to final demand (excluding industrial investment and education). The row each of the industries defined. The number of columns depends upon the number of final demand sectors chosen (e.g. Personal Consumption, Exports, Net Inventory Change, etc.). For each final demand sector, therefore, the column representing that sector shows the amount of goods and services purchased during the given year from each of the industries. The total production of each industry is given by the sum of all deliveries to industry, education and final demand. For completeness, this sum is included as column (X) in the accounts. Column (X) represents the Total column appearing at the right hand side of the G.A.M.E. input-output table. The rest of final demand table used in the G.A.M.E. Seminar is of dimension 23-by-6. The five tables thus far described form the expanded set of inter-industry accounts used in the G.A.M.E. Seminar.

6. Manpower Employed by Industry (Table N_1).

17. This table records the number of individuals employed during the given year in each defined industry according to their occupation. Thus, each row of the table represents one of the occupations defined according to the occupational classification, and the entries in this row indicate the number of individuals holding this occupation in each of the industries. Alternatively, each column in the table indicates the number of individuals employed by each industry, according to their occupation. A typical entry in this table would be the number of engineers employed by the petroleum industry during the given year. This entry would appear at the intersection of the row representing the occupation of engineer and the column representing the petroleum industry. If salaries are substituted for the number of individuals, and other value added is shown for each industry, the total inputs into each industry for the given year will be the sum of all the column entries. It is for this reason that a row labelled "Other Value Added" and a "Total Inputs" row have been included in the accounts, in conformance with usual input-output accounting procedures. In this

form, the total inputs are exactly equal to the total outputs, i.e. to total production. In the G.A.M.E. exercise, however, table (N_1) was constructed on the basis of the number of individuals employed rather than their salary equivalents. The table of manpower employed by industry used in the G.A.M.E. Seminar is of dimension 20-by-23.

7. Manpower Employed by Education (N_2).

18. This table records the number of individuals employed during the given year in each branch of education according to their occupation. It therefore has the same number of rows as defined by the occupational classification. The number of columns is equal to the number of defined educational branches. A typical entry in this table would be the number of secondary school teachers employed in the Upper Secondary Technical branch of education. This entry would appear at the intersection of the row representing the occupation of secondary school teacher and the column representing the Upper Secondary Technical branch. Although a large number of individuals employed as teachers will be recorded in this table, the table will also include administrators and other supporting personnel. It can be expected, however, that a majority of the rows will contain zero entries since many of the defined occupations are not used by education. The table (N_2) appears directly below the table of intermediate goods and purchases by education (X_2) in the same way as the manpower table for industry (N_1) appears beneath the input-output table for industry (X_1). If salaries are substituted for the number of individuals employed in table (N_2), the total expenditure on current account for each branch of education is obtained by summing down the column representing that branch in tables (X_2) and (N_2). In the G A.M.E. exercise, however, table (N_2) was constructed on the basis of the number of individuals employed rather than their salary equivalents. The table of manpower employed by education used in the G.A.M.E. Seminar is of dimension 20-by-7.

8. Manpower Employed by the Rest of Final Demand (N_{FD}).

19. Since there remain final demand secotrs which employ manpower, this table is designed to record these individuals. The final demand sectors shown will be identical to those defined for the table recording the goods and services delivered to the rest of final demand. In this way, table (N_{FD}) will appear in the accounts directly beneath table (X_{FD}). Most of the sectors,

however, will show no employment. The total number of individuals employed in a given occupation for the given year is the sum of those employed in industry, education and the rest of final demand. This sum is entered at the right of the accounts in the column labelled (N). The table of manpower employed by the rest of final demand used in the G.A.M.E. Seminar is of dimension 20-by-6.

9. Educational Distribution of the Active Labour Force (O).

20. This table shows the educational qualifications of the individuals employed in each occupation for the given year. Each row, therefore, represents one of the defined occupations and each column one of the defined educational qualifications. Given the total number of individuals employed in a given occupation during the year, these individuals are distributed across the row representing that occupation in accordance with the educational qualifications which they possess. A column shows how many people with a given qualification are employed in each of the occupations. The sum across the rows gives a vector which is identical to the total employment vector (N) appearing at the right hand side of the accounts. The table of educational qualifications of the active labour force used in G.A.M.E. is of dimension 20-by-8.

21. It will be noted that tables (N_1), (N_2) and (N_{FD}) defined above provide a disaggregated set of accounts of the active labour force showing both where individuals were employed and what occupation they held. Table (O) re-dissagregates this same labour force to relate information about educational qualifications and occupations. For purposes of describing the accounts in the G.A.M.E. Seminar, the terms "active" and "employed" were used interchangeably for simplification. When table (O) includes employed and unemployed, the total number of individuals recorded in this table will differ slightly from the sum of individuals included in tables (N_1), (N_2) and (N_{FD}). Such differences are primarily a matter of the sources of data used to obtain the two tables. For purposes of obtaining the coefficients described below, either of the two formulations can be considered equivalent for table (O), since the differences in the coefficients obtained for the two formulations are statistically insignificant. The four types of manpower tables described above form the basis of the G.A.M.E. manpower accounts.

10. School Leavers .

22. This table shows the number of individuals who were in the educational system at the start of the given year, but were no longer in the system at the end of the year (or, more precisely, at the start of the next year.) Thus, the table records the flow of students from the educational system to the labour force. Each row of the table represents the branch and

grade in which the student was enrolled at the start of the year in accordance with the educational classification. The columns represent the educational qualification with which the student leaves the educational system. Thus, each row contains the number of school leavers during the given year from a particular branch and grade of education. These leavers may include both drop-outs and graduates, and their educational qualifications will differ accordingly. A column contains the number of individuals who leave the educational system during the year having attained the educational qualification represented by that column. A typical entry would be the number of students who graduated from the Upper Secondary General branch and entered the active labour force without continuing to a more advanced branch. This entry would appear at the intersection of the row representing the last year of study in the Upper Secondary General branch and the column representing the Upper Secondary General qualification. This table also contains two additional columns on the right hand side for completeness of the accounts. The first column permits student deaths during the year to be recorded, the second records those school leavers who are unavailable for employment. The school leaver table appears directly below the table of the educational distribution of the active labour force. The school leaver table used in the G.A.M.E. Seminar was of dimension 25-by-10.

11. Inter-Educational Flows (E).

23. This table represents the flows of students within various branches and grades of education. It is a square table, the number of rows and columns depending upon the classification of education used. Each row contains the number of individuals who were enrolled in the branch and grade of education represented by that row at the start of the given year who continue their education at the start of the next year. These individuals are distributed according to the branch and grade of education in which they are enrolled at the start of the next year. The table thus shows the flows of students within the educational system during a one-year period. Alternatively, each column represents the number of people enrolled in that particular branch and grade of education at the start of the next year, these students being distributed according to where they were enrolled at the start of the given year. Thus, the intersection of the row representing the second grade of the Compulsory branch and the column representing the third grade of the same branch will contain the number of students who advanced from the second to the third grade in the Compulsory branch during that year. Repeaters will always be found on the diagonal. The inter-educational flow table used in the G.A.M.E. Seminar was of dimension 25-by-25.

24. Summing across each row of tables (E) and (L) gives the total number of students enrolled in each branch and grade of

education at the start of the given year ($S^{(t)}$). This vector is shown at the far right hand side of the integrated accounts in Figure 1. By adding a row of new entrants into the educational system during the given year (E_N), the total enrolments by branch and grade of education at the start of the next year ($S^{(t+1)}$) can also be included in the accounts. These two rows are shown beneath table (E) in Figure 1. Tables (E) and (L) form the basis of the educational flow accounts.

25. For purposes of the G.A.M.E. Seminar, this set of integrated accounts was designed to bring together, in a unified framework, the numerous individual accounts which were compiled by each of the three groups working in isolation or in pairs during the first week of the seminar. Participants constructed this set of accounts for the base year of the G.A.N.E. exercise on the basis of data provided them. The framework above seeks to integrate flows of goods and services as well as flows of humans. In this way, it was possible for participants to obtain a quantitative "picture" of the G.A.M.E. economy during the base year in terms of its production and use of goods and services, its use of manpower, and its training of additional individuals who will later enter the labour force.

26. As was mentioned in the body of this paper, these accounts were used by participants in the G.A.M.E. Seminar to derive an integrated set of coefficients for estimating parameters in the G.A.M.E. Model. The manner in which these coefficients are derived from the accounts is described below.

III. EDUCATION, MANPOWER AND INTER-INDUSTRY COEFFICIENTS.

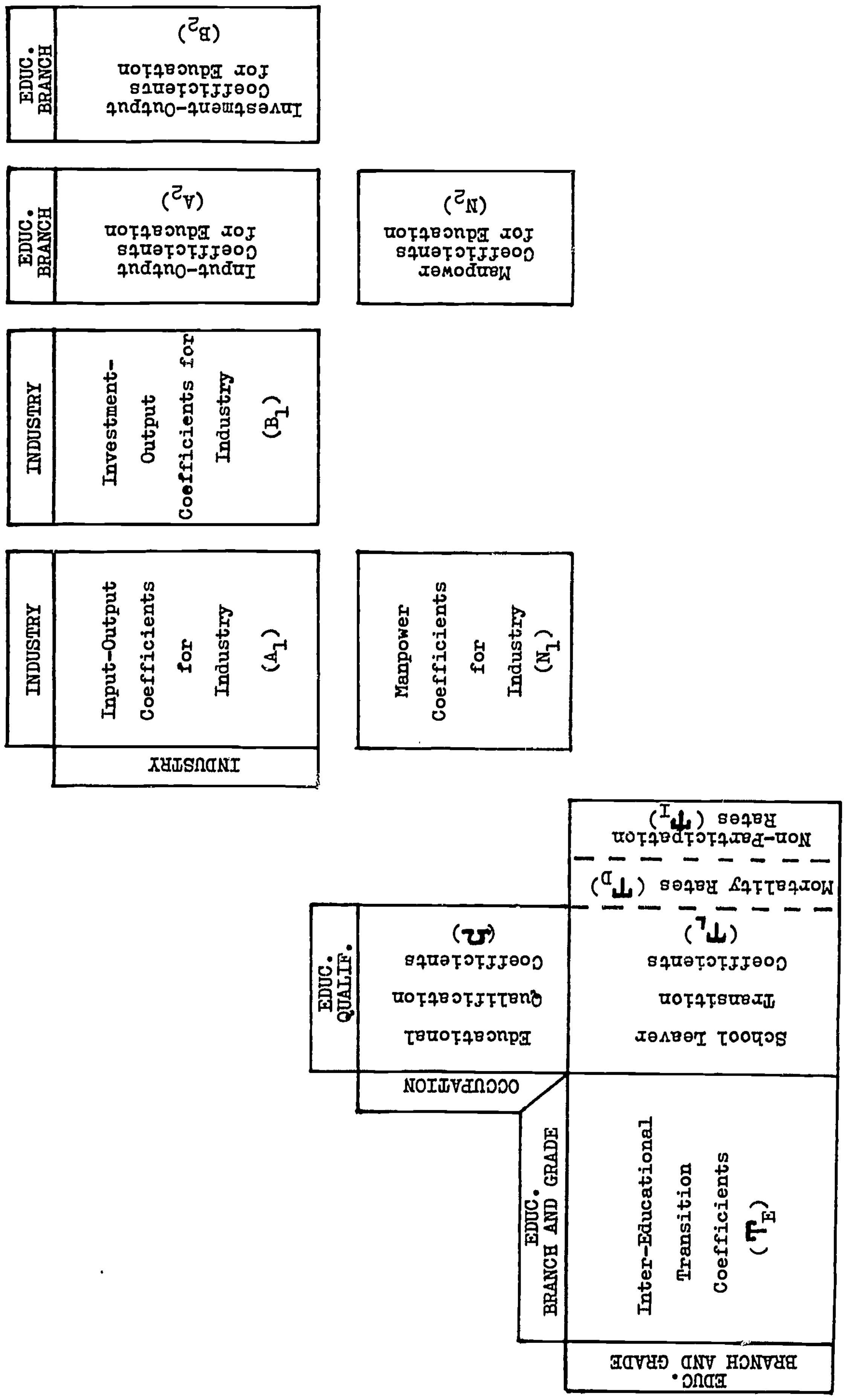
27. Because the integrated set of accounts shown in Figure 1 will be used to derive the education, manpower and inter-industry coefficients, these coefficients can be arranged in a unified framework which is very similar to that of the accounts themselves. This integrated set of coefficients matrices to be derived from the accounts is given in Figure 2 on the following page. It is seen that Figure 2 closely resembles the integrated accounts in Figure 1. Each of the coefficients matrices appearing in Figure 2 is described separately below.

1. Input-Output Coefficients for Industry (A_1).

28. This matrix is obtained from the accounts by dividing each column in table (X_1) in Figure 1 by the total production (X) of the industry corresponding to that column. In this way, table (X_1) is converted to a matrix of input-output coefficients. Each coefficient appearing in a column in this matrix shows the amount of each type of intermediate good used to produce one unit of output by the industry represented by the column.

FIGURE 2

EDUCATION, MANPOWER, INTER-INDUSTRY COEFFICIENTS



2. Manpower Coefficients for Industry (η_1).

29. To obtain this matrix, each column in table (N_1) in Figure 1 is also divided by the total production (X) of the industry corresponding to that column. The result is a matrix of manpower coefficients for industry. Each coefficient appearing in a column of this matrix shows the number of individuals each occupation required for one year to produce one unit of output by the industry represented by the column. Since the total production values are often given in units of millions, these coefficients are often normalized to represent the number employed per million units of gross output.

3. Investment-Output Coefficients for Industry (B_1).

30. In the same way in which the columns in table (X_1) were divided by the values of total production to obtain the input-output coefficients matrix, each column in table (K_1) in Figure 1 can be divided by the total production (X) of the industry corresponding to that column to obtain a matrix of investment-output coefficients. Each column of coefficients shows the amount of each type of investment good purchased during the given year per unit of output produced by the industry represented by the column.

31. The three coefficients matrices described above show the intermediate input, manpower and investment structures of each industry for the given year.

4. Input-Output Coefficients for Education (A_2).

32. This matrix is obtained by dividing each column in table (X_2) in Figure 1 by the total enrolments in the branch of education corresponding to the column. The convention chosen for G.A.M.E. was to use the enrolments at the end of the given year ($S^{(t+1)}$). The coefficients in a column of this matrix show the current expenditure on each type of good per student enrolled in the branch of education represented by the column.

5. Manpower Coefficients for Education (η_2).

33. In the same way in which it was possible to derive a set of manpower coefficnents for industry, it is possible to derive a set of manpower coefficients for education from the accounts. In this case, each column of the manpower account for education (N_2) in Figure 1 is divided by the total enrolment

at the end of the given year ($S^{(t+1)}$) in the branch of education represented by that column. A column of manpower coefficients for education shows the number of individuals in each occupation employed in a given branch of education per student enrolled.

6. Investment-Output Coefficients for Education (B_2).

34. The investment-output coefficients matrix for education is obtainded by dividing each column in table (K_2) in figure 1 by the total enrolment at the end of the given year ($S^{(t+1)}$) in the branch of education corresponding to that column. Each column in this matrix shows the amount of each type of investment good purchased during the given year per student enrolled in the branch of education represented by the column.

35. The three coefficients matrices described immediately above show the intermediate input, manpower and investment structures of each branch of education for the given year.

7. Educational Qualification Coefficients (Ω).

36. Table (O) in Figure 1 can be converted to a set of coefficients representing the educational qualifications of the active labour force, simply by dividing the entries in each row in the table by the row total. If multiplied by 100, these coefficients would be identical to the percentage distribution of educational qualifications in each occupation. These coefficients describe the educational qualfication structure of the labour force. Each coefficient shows the proportion of individuals employed in the occupation represented by the row in which the coefficien appears who have the educational qualification represented by the column in which it is found.

8. Educational Transition Coefficients (T).

37. The Inter-Educational Transition Coefficients (T_E) and the School Leaver Transition Coefficients (T_L) are two submatrices of the complete matrix of transition coefficients for the educational system. These two matrices can be obtained by dividing each row in the tables (E) and (L) in Figure 1 by the total enrolments at the beginning of the year ($S^{(t)}$) in the branch and grade of education represented by that row. Because student deaths and non-participating school leavers are included in the educational flow accounts, this division by total enrolments at the start of the period will also yield the student mortality rates (T_D) and school-leaver non-participation rates (T_N). The inter-educational transition coefficients show the

proportion of students who move from one branch and grade of education to another (or repeat) during the given year. The school-leaver transition coefficients show the proportion of students who leave a given branch and grade of education during the year with the educational qualification represented by the column in which the coefficient is found.

APPENDIX 3

DESCRIPTION OF THE G.A.M.E. SIMULATION EXERCISE

DESCRIPTION OF THE G.A.M.E. SIMULATION EXERCISE

I. INTRODUCTION.

1. During the G.A.M.E. Seminar, participants were divided into three groups: the Education Group, the Manpower Group and the Economic Group. The G.A.M.E. Simulation Exercise consisted of the construction and the use of three sub-models. These sub-models, when considered together, form the G.A.M.E. Educational Planning Model. The construction of the models involved an extension of the accounting relationships established in the integrated accounts described in Appendix 2.

2. The simulation was constructed in 3 stages. Each stage successively brought the participants closer to an overall plan reflecting a reasonably consistent solution. This was realized through a step-wise man-machine interaction. The 3 stages are:

(1) Programmes Formulated in Isolation;

(2) Uni-directionally Determined Programmes;

(3) Iteratively Balanced Programmes.

II. PROGRAMMES FORMULATED IN ISOLATION.

3. During this stage, each group postulated a set of preferences in advance. These preferences were translated into quantitative terms. For example, the Education Group expressed its preferences quantitatively by postulating certain changes in the educational transition coefficients.

4. Having expressed their preferences in quantitative terms, each group then used its model to solve for certain requirements which satisfied its preference. For instance, the Economic Group solved for the manpower and production levels required to meet its preferred final demand.

5. Each group then presented its programme in terms of its targets and requirements. These isolated programmes, which were independently arrived at, were subjected to a confrontation with each other, at which time each group submitted its demands to the other two groups. After considering the demands, an inevitable impasse was reached. This impasse was brought about by the failure of the groups to interact during the formulation of the preferences and the programmes. It was therefore necessary to seek an alternative mode of programme formulation.

III. UNI-DIRECTIONALLY DETERMINED PROGRAMMES.

6. For this stage of the exercise, the sequence of steps was initiated by the Education Group, which began by reformulating its preferences and its programme in the light of the experience gained in the first stage. This resulted in a new set of manpower and economic requirements for education.

7. The production requirements were then channelled to the Economic Group, which reformulated its programme to satisfy the demands made by the Education Group. On the basis of this revised programme, the Economic Group arrived at a new set of manpower and production requirements. These manpower requirements, in turn, were channelled to the Manpower Group. Meanwhile, the Education Group had channelled its manpower requirements to the Manpower Group.

8. At this point, the Manpower Group re-formulated its programme in an attempt to satisfy all the manpower requirements. But in order to do so, it had to determine its requirements for qualified personnel over the plan period. Only the Education Group could satisfy this demand.

9 Whether or not the Education Group was able to make available the required qualified personnel depended upon the educational programme it formulated at the beginning of the cycle. It was found that the requirements and availabilities of qualified personnel were not compatible, and therefore a second impasse was reached. It was also discovered that even if these requirements had been met, the overall plan would not have been satisfactory from the point of view of the Economic and Manpower groups, since in satisfying the Education group, it had been necessary to violate some of the other groups preferences. This being the case, a fresh attempt had to be made to secure a mutually satisfactory plan in which new targets and requirements for all groups would achieve a balance.

IV ITERATIVELY BALANCED PROGRAMMES

10. In order to achieve mutually balanced programmes, it became clear that it was essential that all groups maintain a continuous interaction. This interaction permitted a number of iterations to be carried out. Each group's programme was subjected to a critical evaluation by the other groups, in order to force the group towards a greater realism by revising its targets downward. Such revisions resulted in lower levels of requirements. By iteratively applying this procedure, the programmes of all groups must eventually converge to a mutually consistent and balanced overall plan.

V. PURPOSE OF THIS EXERCISE.

11. This exercise allowed the G.A.M.E. participants to use a mathematical planning model within a simulated planning environment. The model itself was constructed by the participants

on the basis of empirical data. The iterative procedure used from solving the model reflects, to a large extent, the planning process as it is carried out in the real world. The didactic simulation exercise demonstrated the following principles of planning:

(1) Plans for education, manpower and the economy formulated in isolation are dysfunctional;

(2) Even though the manpower and production requirements of educational programmes are made explicit, there is no guarantee that these requirements will be compatible with the programmes of others;

(3) Only by an explicit consideration of the interdependent relationships among education, manpower and the economy can consistency in planning be achieved.